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SANIO'S LAWS FOR THE VARIATION IN SIZE OF CONIFEROUS TRACHEIDS

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In 1872 SANIO¹ published the results of an investigation upon the tracheids of Scotch pine, *Pinus sylvestris* L. From his observations and measurements he deduced five general laws which may be translated as follows:

1. In the stem and branches the tracheids everywhere increase in size from within outward, throughout a number of annual rings, until they have attained a definite size, which then remains constant for the following annual rings.

2. The constant final size changes in the stem in such a manner that it constantly increases from below upward, reaches its maximum at a definite height, and then diminishes toward the summit.

3. The final size of the tracheids in the branches is less than in the stem, but is dependent on the latter, inasmuch as those branches which arise from the stem at a level where the tracheids are larger themselves have larger tracheids than those which arise at a level where the constant size is less.

4. In the gnarled branches of the summit the constant size in the outer rings increases toward the apex, and then falls again, but here irregularities occur which may be absent in regularly grown branches.

5. In the root the width of the elements first increases, then falls, and next rises to a constant figure. An increase in length also takes place, but could not be exactly determined.

SANIO's measurements and conclusions have been accepted by DEBARY, PFEFFER, HABERLANDT, and others and have been considered to be applicable to conifers in general.

¹ SANIO, KARL, Über die Grösse der Holzzellen bei der gemeinen der Kiefer (*Pinus sylvestris*). Jahrb. Wiss. Bot. 8:401-420. 1872.

The writers recently had occasion to test the validity of SANIO's first two laws in connection with an investigation undertaken in the endeavor to secure a simple method for segregating long and short "fibers" in the manufacture of raw wood pulp. The following North American conifers were studied: *Pinus Strobus* L., *P. palustris* Mill., *Picea rubens* Sarg., *Tsuga canadensis* Carr., and *Abies concolor* Lindl. and Gord. Chips of wood were removed from the specimens and were macerated by the use of a 5 per cent solution of equal parts of chromic and nitric acid. The tracheids were separated after maceration by being shaken with water and glass beads, insuring minimum breakage. They were then kept in a mixture of 95 per cent alcohol and chloroform to prevent softening. The measurements were made with a micrometer eyepiece, 50 measurements from each chip. The results obtained are shown in the following tables:

EFFECT OF AGE ON THE LENGTH OF TRACHEIDS

TABLE I

Pinus Strobus, 120 ANNUAL RINGS, CROSS-SECTION 1 FOOT FROM GROUND

ANNUAL RING	TRACHEID LENGTHS—MILLIMETERS			ANNUAL RING	TRACHEID LENGTHS—MILLIMETERS		
	Max.	Min.	Av.		Max.	Min.	Av.
20.....	3.35	1.60	2.65	80.....	5.10	2.65	3.77
30.....	3.65	2.35	3.02	90.....	4.60	2.50	3.79
40.....	4.80	2.55	3.64	100.....	4.65	2.50	3.85
50.....	4.20	2.35	3.30	110.....	4.45	3.20	3.91
60.....	4.65	2.45	3.47	120.....	5.40	3.45	4.20
70.....	4.80	2.65	3.52				

TABLE II

Abies concolor, 80 ANNUAL RINGS, ELEVATION OF CROSS-SECTION UNKNOWN

ANNUAL RING	TRACHEID LENGTHS—MILLIMETERS			ANNUAL RING	TRACHEID LENGTHS—MILLIMETERS		
	Max.	Min.	Av.		Max.	Min.	Av.
10.....	3.50	2.20	2.75	50.....	5.45	3.30	4.45
20.....	3.90	2.40	3.30	60.....	5.45	3.55	4.04
30.....	4.90	2.50	3.65	70.....	6.30	3.50	5.02
40.....	5.65	2.15	3.58	80.....	6.45	3.55	5.20

TABLE III

Pinus palustris, 230 ANNUAL RINGS, CROSS-SECTION 1 FOOT FROM GROUND

ANNUAL RING	TRACHEID LENGTHS—MILLIMETERS			ANNUAL RING	TRACHEID LENGTHS—MILLIMETERS		
	Max.	Min.	Av.		Max.	Min.	Av.
10.....	3.00	1.80	2.42	130.....	5.90	3.90	4.99
20.....	3.85	2.40	3.06	140.....	6.25	3.75	4.92
30.....	4.50	2.80	3.70	150.....	6.00	4.00	4.87
40.....	4.95	2.80	4.06	160.....	6.20	4.00	5.08
50.....	5.30	2.95	4.11	170.....	6.05	3.45	4.57
60.....	6.05	3.05	4.33	180.....	5.75	3.40	4.10
70.....	5.25	2.85	3.92	190.....	5.50	3.10	4.03
80.....	5.70	3.05	4.41	200.....	6.20	3.15	4.42
90.....	6.05	3.20	4.66	210.....	6.05	3.35	4.66
100.....	6.30	3.45	4.88	220.....	5.90	3.10	4.35
110.....	6.05	3.60	4.57	230.....	5.20	2.85	4.00
120.....	5.80	3.85	4.66				

TABLE IV

Tsuga canadensis, 80 ANNUAL RINGS, CROSS-SECTION 1 FOOT FROM GROUND

ANNUAL RING	TRACHEID LENGTHS—MILLIMETERS			ANNUAL RING	TRACHEID LENGTHS—MILLIMETERS		
	Max.	Min.	Av.		Max.	Min.	Av.
10.....	2.30	0.95	1.63	50.....	4.25	1.85	3.17
20.....	3.20	1.15	2.20	60.....	3.80	1.60	2.48
30.....	3.75	2.05	2.99	70.....	3.20	1.40	2.47
40.....	4.00	2.25	3.16	80.....	3.15	1.80	2.84

EFFECT OF POSITION IN THE VERTICAL AXIS ON THE LENGTH OF TRACHEIDS

TABLE V

Picea rubens, 50 ANNUAL RINGS, AVERAGE TRACHEID LENGTH IN MILLIMETERS

Annual ring	Distance from ground in feet					
	1	6	12	18	24	30
10.....	1.68
20.....	2.21	2.49	2.22
30.....	2.58	2.92	2.84	2.49	1.89
40.....	3.17	3.00	3.48	3.31	3.23	2.71
50.....	3.48	3.56	3.84	3.70	3.87	3.31

EFFECT OF WIDTH OF RING UPON THE
LENGTH OF TRACHEIDS

TABLE VI

Pinus Strobus, ECCENTRICITY DUE TO FASTER GROWTH ON
ONE SIDE, AVERAGE

ANNUAL RING	TRACHEID LENGTHS— MILLIMETERS	
	Narrow	Wide
10.....	1.63	1.66
22.....	2.58	2.41
27.....	2.51	2.53
Average.....	2.24	2.20

Discussion of measurements and conclusions

The results of these measurements are obviously not in accord with SANIO's first law, since no constant tracheid length was found in any of the specimens examined. Inasmuch as SANIO found a constant in all cases within the 50th ring, and in one case within the 20th, and this study found none, even within the 230th, it is evident that SANIO's first law cannot be applied to conifers, and some doubt is cast upon the accuracy of his observations upon Scotch pine. As is shown diagrammatically in the accompanying figure, the length of the tracheids increases rapidly for a period of years varying from 25 to 60. At the end of this period there is a marked falling off in the length of the tracheids, which lasts for a decade or more. Subsequently the tracheids again increase in length. In the case of the long-leaf pine, which unfortunately was the only very old material available, the tracheid length reaches a maximum at 160 years and decreases, with one marked period of recovery, during succeeding rings. The factor or factors which produce the fairly regular cycles or series of crests and depressions which occur in the long-leaf pine curve are obscure and deserve to be studied carefully by some one who has easy access to old coniferous trees. DOUGLASS² and HUNTINGTON'S³ interesting correlations

² DOUGLASS, A. E., Weather cycles in the growth of big trees. Monthly Weather Review. June 1909.

³ HUNTINGTON, ELLSWORTH, The climatic factor. Carnegie Inst. Washington, D.C. 1914.

between rainfall and ring width suggest the possibility that the dimensions of tracheids may be equally sensitive to modifying climatic factors.

It is evident from Table V that SANIO's second law is applicable to *Picea rubens* as well as to *Pinus sylvestris*. However, a fact unnoted by SANIO is that the maximum average tracheid length occurs higher from the ground in rings nearer to the bark. This probably bears a relation to the fact that each successive increment is larger, that is, extends farther from the ground. The study of

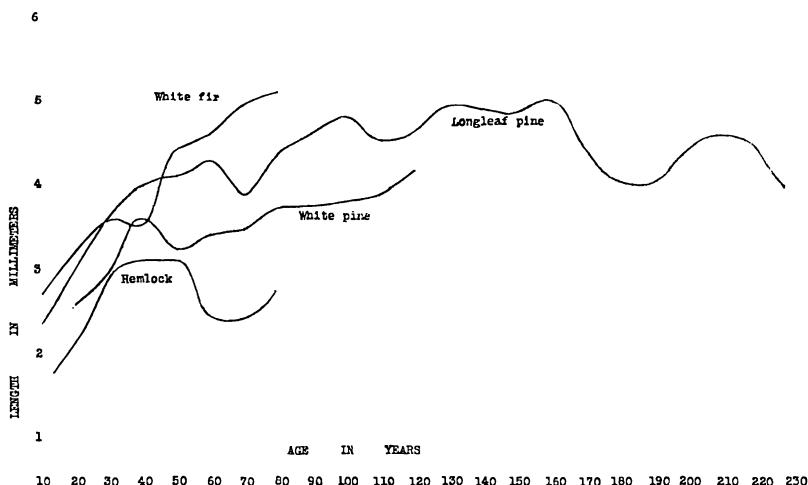


FIG. 1

the eccentric cross-section recorded in table VI seems to indicate that width of ring has no marked effect upon the length of tracheids.

A number of botanists have endeavored to make use of the dimensions of the xylem elements in the classification and identification of the secondary wood of living and fossil plants. When based upon the study of a limited amount of material taken from a given region in a tree, the measurements are significant only if compared with those secured from a homologous region in a tree which has grown under similar conditions. Average dimensions

for a species must obviously be based upon a large amount of material selected from mature plants grown in different environments. However, general averages of this character are of little value for the purposes of the systematic botanist, or in the identification of woody tissues, and are only of relative value to the manufacturer of wood pulp.

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